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decay of ponderosa pine sawtimber in the black hills

By Thomas E. Hinds

ocky Mountain Forest & Range Experiment Station

orest Service — U.S. Department of Agriculture

Fort Collins, Colorado 80521

Abstract

A defect study of 1,725 logs cut from 498 trees provided the basis for determining the relationships between tree age, volume, and defect. Red rot was responsible for 8.6 percent, brown rots 7.3 percent, and other defects 3.3 percent of the total 19.2 percent defect. Red rot, found in 68 percent of all trees, was the most important cause of defect.

Key words: Polyporus anceps Pk., Pinus ponderosa, lumber quality, tree volume estimates.

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Decay of Ponderosa Pine Sawtimber in the Black Hills[1]

by

Thomas E. Hinds, Plant Pathologist

Rocky Mountain Forest and Range Experiment Station[2]

[1]From a thesis submitted in partial fulfillment of the requirements for a M. S. degree at Colorado State University.
[2]Central headquarters maintained at Fort Collins, in cooperation with Colorado State University.

Contents

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Thomas E. Hinds

Introduction

Commercial forest lands in the Black Hills of western South Dakota cover approximately 1.3 million acres and contain 3.3 billion board feet of sawtimber (Choate and Spencer 1969). Ponderosa pine (Pinus ponderosa Laws.) makes up 95 percent of the total volume. The net annual growth of pine sawtimber in the Black Hills in 1969 was estimated to be 86.5 million board feet, whereas the annual cut amounted to 53.2 million board feet (International 1/4-inch log rule). The lumber industry in the Black Hills is threatened less by shortages in raw material than by competition from other construction materials for markets formerly served by common grades of lumber (Mueller and Kovner 1967). Accordingly, the industry continually requires a general tightening up in all expenditures and practices. Errors in estimating volume and quality of timber, or logging or milling costs and lumber yields, can be serious in the lumber industry. Many of these errors result from failure to identify and make proper allowances for defect.

Defect has been recognized as a serious problem in Black Hills ponderosa pine for many years. According to Hoffman and Krueger (1949), the timber has always had a high cull factor (15 to 35 percent). It has been reported that losses from red rot, caused by Polyporus anceps Pk., in old-growth stands amounted to about 25 percent of the volume cut (Andrews and Gill 1941). The only mensurational study of red rot in the Black Hills dealt with factors affecting rot incidence in immature stands up to 140 years of age, however, and did not provide any data on volume losses in sawtimber (Andrews and Gill 1941).

In 1962, a cooperative lumber grade recovery study by the USDA Forest Service and private industry[3] provided an opportunity to determine the volume and significance of red rot and other heart rots in older merchantable-sized trees. One of the secondary objectives of the lumber grade recovery study was to develop improved criteria for identifying the presence and extent of scalable rot defects. More importantly from a pathological standpoint, however, the study enabled us to investigate the relationship of rot to various characteristics of trees, stands, and sites, as well as identify associated decay fungi.

Methods

The decay study was limited to the 498 trees selected for the lumber grade recovery study. These selections were made according to criteria designed to insure a reasonably representative sample of all diameters and log grade classes available in the Black Hills (Mueller and Kovner 1967). The trees were randomly selected, as far as possible, within these classes from trees marked for cutting on sale areas on 5 of the 10 Ranger Districts of the Black Hills National Forest (fig. 1).

The lumber grade recovery study provided stand and tree measurement data for each tree. Stand

[3] *The Ventling-Richtman Sawmill and the Custer Lumber Planing Mill provided the use of their plant facilities. The Buckingham Wood Products Company and the Homestake Mining Company provided men and equipment needed to select and handle the sample trees and logs. Others who assisted include the Western Wood Products Association, and the Forest Products Laboratory and the Western Pine Log Grade Project of the USDA Forest Service.*

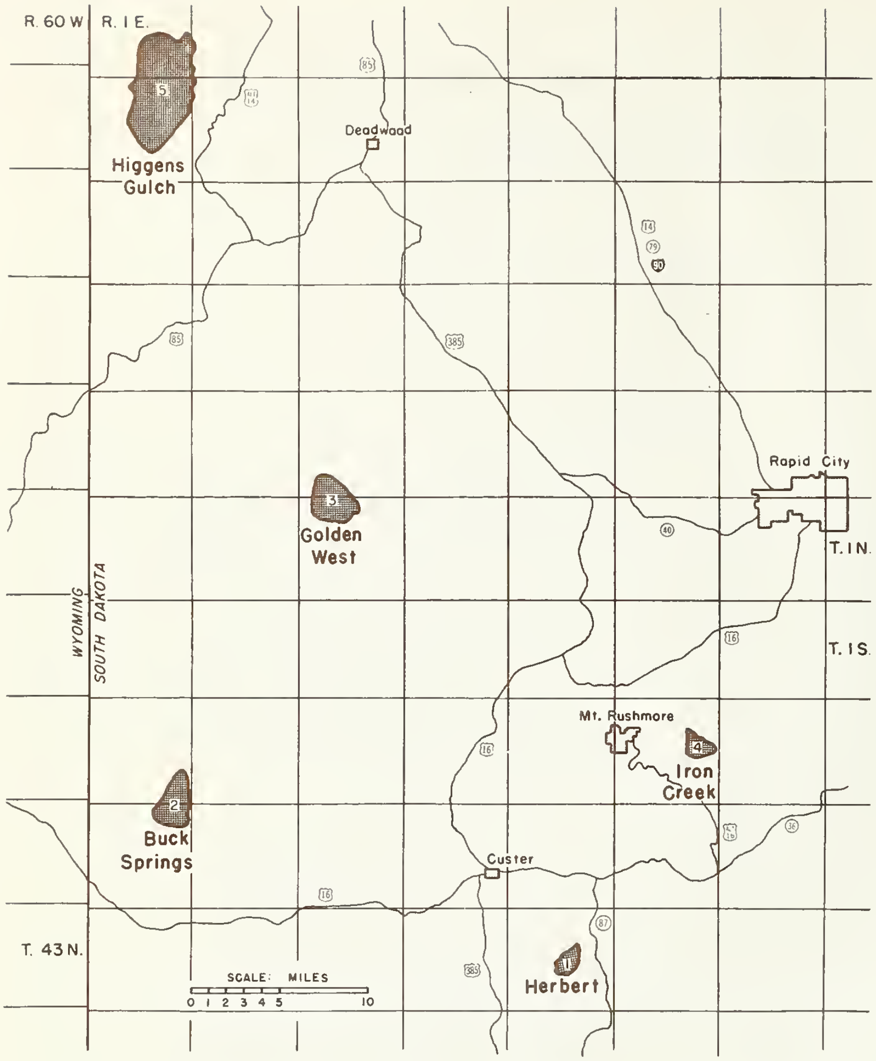

Figure 1.--Location of five sale areas from which trees were selected in the Black Hills National Forest in South Dakota.

data included stand age, soil type, aspect, slope gradient, slope position, stand density, and site index. Tree measurement data included crown class, crown density, crown length, stump height, tree height, height to first live and dead branch, height of the clear bole and to the base of the tree crown, tree diameter, and bark retention on dead branch stubs (a reliable indicator of red rot in 60- to 100-year-old trees in the Southwest). After trees were felled, bucked, and scaled, tree and log numbers were painted on each log end, and log length was recorded on a tree measurement form. All merchantable logs (a net scale of one-third or more of the gross log scale) were deposited at the sawmill yard.

Various log dimensions and surface defects were recorded for each log on a standard form, which included a cross-sectional diagram of both log ends. Supplemental data on type, stage, and amount of visible decay on log ends were diagramed on the form. Each log was then rescaled by USDA Forest Service and Western Wood Products Association check scalers. All gross, net, and defect volumes were identified by tree and log number.

Debarked logs suitable for canting were sawed into cants on a circular head rig and passed to a sash gang saw where they were cut into 1-inch boards (fig. 2). Salvable lumber from a few logs too defective for canting was routed directly to the edger. The boards of all logs containing decay that were routed through the sash gang saw were photographed as they were laid out and numbered on a slow-moving transfer chain leading to the edger (fig. 3). A 35 mm. reflex camera with a 28 mm. wide-angle lens was used in conjunction with two strobe lights placed overhead at 45° angles to the long dimension of the boards. The rough green

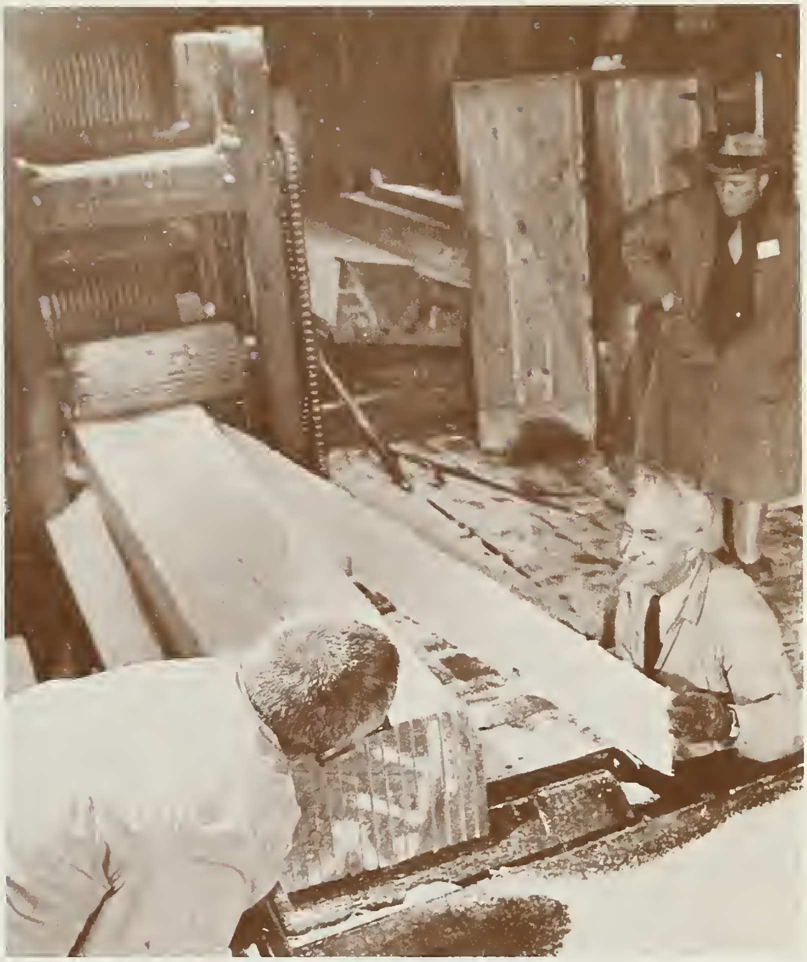

Figure 2.--Sash gang cutting cants (at rear of saw) into 1-inch boards (foreground).

Figure 3.--Boards of a cant containing red rot laid out for numbering and photographing.

lumber was edged, trimmed, sorted, graded, kiln dried, and finished for other volume comparisons.

Cull logs and segments left in the woods were examined to complete the records on defect. These were cut into 4-foot sections to reveal the extent and type of decay. Fungi from decaying wood were cultured for identification. To aid in the culture identifications, sporophores of decay fungi were collected in the five areas during July 1965. All sporophores and decay cultures were sent to the USDA Forest Disease Laboratory, Laurel, Maryland, for identification.

All merchantable and cull log data from the lumber grade recovery study (Mueller and Kovner 1967) were used in this decay analysis. Since the net volume determined by the Forest Service log scale (Scribner Decimal C rule) was within 1 percent of the total lumber produced (dry finish basis), the Forest Service scale data were used.

Pictures of decayed boards were enlarged to 7 diameters. A plastic scale overlay was made to fit the pictures so that length of decay columns in the boards could be measured. Cubic-foot volume was calculated for each log by Smalian's formula. Rot volume was calculated in the same way, except that where rot ended within a log it was treated as a cone.

Results and Discussion

A total of 1,725 logs was cut from the 498 trees. Rot defect amounted to 15.9 percent and total defect 19.2 percent of the gross board-foot volume (table 1). All white-pocket rot was assumed to be red rot, although laboratory study may reveal that P. anceps is not the only cause of this type of decay. Red rot was responsible for slightly more defect than brown cubical rots (8.6 and 7.3 percent, respectively). The remaining 3.3 percent was attributed to other defects such as cat faces, checks or splits, crotch or fork, crook or sweep, fire scar, lightning scar, and other unclassified injuries. Red rot was present in 68 percent of the trees, whereas brown cubical rots were present in only 36 percent; 27 percent of the trees contained both red rot and brown rot. Red rot amounted to 45 percent of the defect, brown rot 38 percent, and other defects 17 percent.

Defect and Log Position

The incidence of defect by log position is given in table 2 and the volumes involved in table 3.

Butt logs contained 42 percent of the total gross volume and 30 percent of the total defect. Of this butt log defect, red rot was responsible for 4.5 percent, brown rot 16.1 percent, and other defects 9.4 percent. Although the incidence of other defect was higher in the butt log, it did not cause as much volume loss as brown rot. All other logs contained 58 percent of the gross volume and 70 percent of the total defect. Red rot accounted for 40.6 percent of the defect in the upper logs, brown rot 22.3 percent, and other defects 7.1 percent. Red rot is thus the most important defect in the upper, smaller logs, while brown rot is the most important in butt logs (tables 2, 3).

Table 1.--Summary of basic data from the five study areas

Area	Number of trees	Average age	Average d.b.h.	Total tree volume (Scribner Dec. C scale)		Total percent rot	
		Years	Inches	Bd. ft.	Cu. ft.	Bd. ft.	Cu. ft.
Buck Springs	100	182	18.2	31,170	5,778.9	19.0	7.3
Golden West	100	223	18.1	35,670	6,731.2	19.9	9.9
Herbert	100	235	17.9	39,690	7,185.4	20.1	8.7
Higgens Gulch	100	167	18.1	39,360	7,284.9	9.9	5.2
Iron Creek	98	179	18.3	36,560	6,829.0	11.7	5.7
All areas	498	197	18.1	182,450	33,809.4	15.9	7.3

Table 2.--Incidence of defect, by log position

Log position	Logs	Defect incidence: Red rot	Brown rot	Other
	No.	- - - - Percent	- - - -	
Log 1	498	12.9	21.7	29.5
Log 2	487	26.5	10.1	9.4
Log 3	380	34.7	10.5	7.4
Log 4	238	40.3	9.7	10.5
Log 5	91	33.0	8.8	10.5
Log 6+	31	22.6	3.2	29.0
Total	1,725	26.5	12.3	15.7

Table 3.--Defect volume, by log position

Log position	Gross volume	Defect volume: Red rot	Brown rot	Other	Total
	Bd. ft.	- - - -	Percent	- - - -	
Log 1	76,840	2.0	7.3	4.3	13.6
Log 2	56,370	8.9	6.5	1.5	16.9
Log 3	31,890	16.7	9.0	1.8	27.5
Log 4	13,170	22.2	8.1	4.3	34.6
Log 5	3,050	27.2	6.2	10.2	43.6
Log 6+	1,130	9.7	.9	16.8	27.4
Total	182,450	8.6	7.3	3.3	19.2

Defect and Tree Age

The relationships between defect and tree age, d.b.h., aspect, slope, stocking, site index, crown class, and crown density were tested by multiple regression analysis for individual areas and for all areas combined. The only significant correlation was between defect and tree age (fig. 4). The slopes of the lines in figure 4 were obtained by regressions, with the number of trees in each 20-year age class (the independent variable) as weights.

The relationship between red rot defect and tree age was expected to be similar to that found in the Southwest (Lightle and Andrews 1968), where red

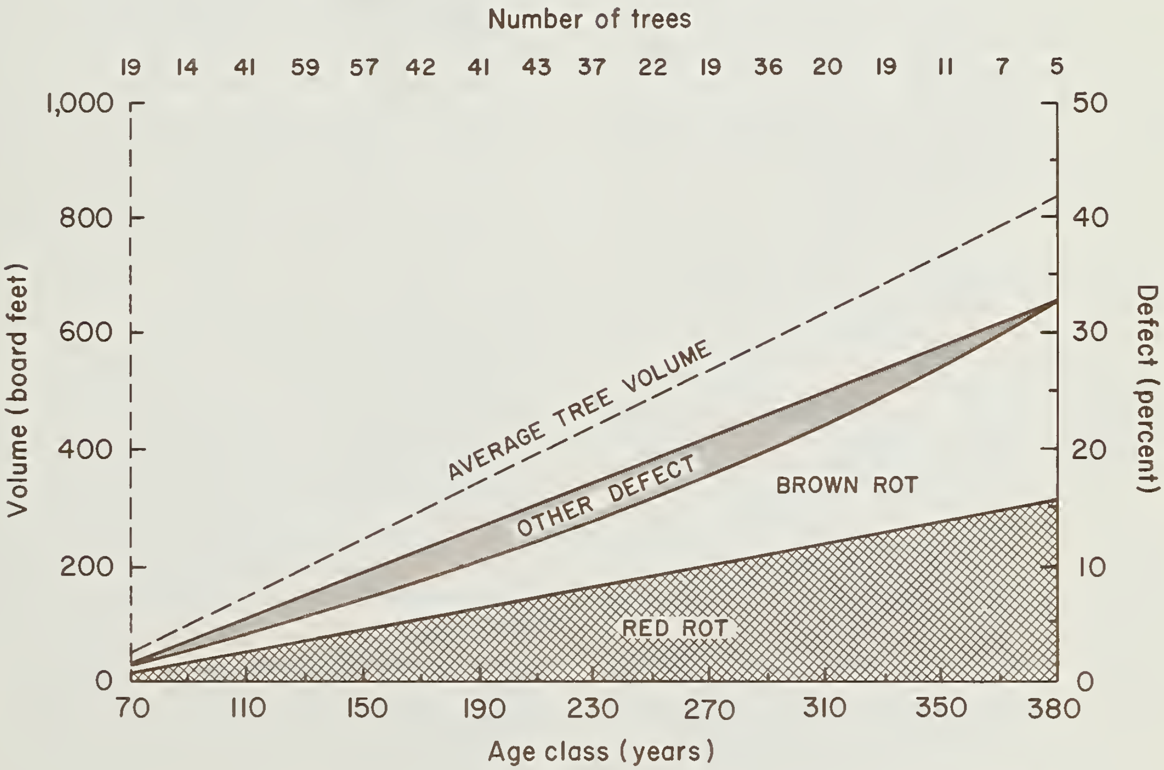

Figure 4.--Relationship between tree age and (1) average gross tree volume and (2) percent defect for ponderosa pine sawtimber in the Black Hills.

rot defect amounted to 10 percent (board-foot basis) at 200 years. In the Black Hills, red rot defect did not reach 10 percent until age 270 years. Red rot defect in the Southwest amounted to 14 percent at 240 years, 19 percent at 300 years, and 25 percent at 380 years in contrast to 8, 11, and 15 percent, respectively, in the Black Hills. Above tree age of 160 years in the Black Hills, the brown rots begin to play a more important role in defect. At ages of 240, 300, and 380 years, the brown rots were responsible for 7, 10, and 18 percent defect. Total rot defect in the Black Hills amounted to little more than red rot defect in the Southwest under 200 years and nearly equal from 200 to 300 years, differing only by 1 or 2 percent. Beyond tree age of 300 years, rot defect was greater in the Black Hills pine.

Andrews and Gill (1941) did not find red rot in the heartwood of immature Black Hills pines under 80 years old, but both incidence and volume increased rapidly after tree age 80. Five trees under 80 years of age contained measurable amounts of red rot in the heartwood in this study. Once red rot has entered the trunk, time is one of the most important factors influencing dimensions of the rot columns. Small pockets of rot may be hidden or too small for scalable defect for many years. The lag between the time red rot reaches the heartwood and the development of scalable defect (table 4) strengthens arguments for shorter rotation periods in the Black Hills.

Table 4.--Relationship of tree age to red rot infection and scalable red rot defect

Tree age class (Years)	Number of trees	Trees with-- Infection	Scalable defect
		- - - Percent	- - - -
60-100	33	18	3
101-140	100	38	14
141-180	99	57	22
181-220	84	76	50
221-260	59	69	59
261-300	55	85	74
301+	62	81	69

Andrews and Gill (1941) found no increase in the percent of butt logs infected with red rot after trees reached the age of about 100 years. By this time, the lower dead branches have fallen or ceased to be entrance points of red rot. Infection points are then established through dead branches higher on the trunk. This progressive infection pattern is important in understanding the defect caused by multiple red rot infections.

Brown rot defect was fairly well distributed throughout the trunk, even though a larger percentage of the butt logs was infected. Six trees in this study were complete culls, and brown rot was responsible for 75 percent of the defect in them. It was more important as a culling factor in the butt log than red rot.

Brown rot was found in only one tree under 80 years old. Incidence of infection increased to 29 percent in the 181- to 220-year age class and to 68 percent in the 301+ class. Scalable brown rot defect was found in 21 and 58 percent of the trees in these tree age classes. Brown rot was more important in the older trees and in the butt logs which contain the greater volumes.

Rot defect can be expected to be less when trees are grown on a shorter rotation period, and cull due to other defects should also decrease. As seen in figure 4, other defects remained small over all ages. Defects other than rot were found in 29 percent of the butt logs (table 2). Old fire scars, the main cause of butt defect, can be expected to decrease in the future with increased fire prevention and control. Forks and dead tops were the major cause of other defects in 57 percent of the logs above the third log. Since stand improvement procedures discriminate against such trees, this type of defect will also decline in the future.

Heart rot losses in sawtimber stands will continue to be large until all older trees have been harvested. Losses will probably amount to at least 15 percent in trees older than 200 years (fig. 4). Rot will continue to be the greatest cause of defect, even in second-growth stands on a 120-year rotation. In such stands red rot losses should not exceed 3 percent, brown rot 2 percent, and other defects 2 percent, for a total of about 7 percent defect. Commercial thinnings may reduce this defect slightly.

Hidden Defect

The presence of interior defect—mainly heart rot—is usually revealed on the ends of saw logs after trees have been felled and bucked. Interior defect that is not so exposed or which is not visible to the scaler is referred to as hidden defect. Of the 1,725 logs in the study, 51 percent were classified as sound; that is, they contained no visible defects before being cut into boards. After sawing, however, only 36 percent of the logs were found to be sound (table 5). Although 15 percent of the logs contained hidden decay, this additional defect did not change the board-foot defect percentage for the study sample. The gross scaled volume of logs with hidden defect amounted to 28,910 board feet, whereas 29,100 board feet of rough dry lumber was produced from them. On a cubic-foot basis, this hidden defect amounted to 0.6 percent of the total volume.

Table 5.--Prevalence of logs with hidden rot defect (board-foot basis)

Classification	Logs with rot defect: Before sawing		Logs with rot defect: After sawing	
	No.	Percent	No.	Percent
Sound	872	51	620	36
Defective	594	34	846	49
Cull	259	15	259	15
Total	1,725	100	1,725	100

Diagnostic Criteria for Red Rot

Red rot is difficult to detect in standing living trees because fruiting bodies are rarely formed on them, and then only on dead branches infected by the fungus. This type of fruiting merely implies the presence of advanced decay in the branch; it does not indicate the vertical extent of heart rot as do Fomes pini sporophores or swollen knots on Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco var. menziesii). Although the lower trunks of mature and overmature trees rarely are completely clear, decayed branches are most likely to be overgrown. On the other hand, the stubs of decayed branches often protrude from the upper trunk, but it is usually impossible to tell from the ground whether they are decayed by red rot or other branch decay fungi. Suspected red rot entrance points in the upper trunk of merchantable trees can sometimes be confirmed by examining matching branch parts on the ground near the base of the trees. The red rot fungus causes the bark to become firmly attached to the wood, a criterion that distinguishes red rot from other decays.

Since neither fruiting bodies nor rotten branches and branch stubs are reliable indicators for heartwood decay, a number of factors were analyzed to determine if any one or combination could be used as indicators of red rot. These factors were bark retention on dead branches, bark distortion or pseudodefect on the surface of the trunk bark that usually has little or no relation to the quality of the wood beneath; other surface defects such as bark pockets, bird peck, bumps, burls, cankers, scars, sweep, branch clusters, and sucker limbs; and height to first live and dead branch. None was found to be a consistent indicator of decay.

Even after trees have been felled and cut into logs, estimates of volume losses are subject to error because (1) hidden decay, and (2) rot visible on the cut ends of logs do not necessarily indicate the volume of wood decayed.

If rot is visible on both ends of a log, it is usually assumed that the rot extends completely through the log. When rot is visible only at one end of a log, the extent of rot penetration into the log is highly variable. Data from Lightle and Andrews (1968) indicated that, in the latter type of log, the area of the log end (inside bark), the area of heartwood, and the total and advanced red rot areas seemed to be related to the volume of rot in the log. Correlation analysis based on 124 study logs in their study was not significant, but indicated the best criterion of defect volume might be the area of advanced red rot. Data from an additional 180 logs from this study still did not improve their results.[4]

Since infection occurs through dead branches, the possibility of multiple entrance points throughout the tree trunk increases with tree age. Once rot reaches the heartwood, it may spread up and down the trunk and coalesce with other decay pockets. Thus in mature trees the decay may be

[4] *Personal communication with Dr. Paul C. Lightle.*

one long column, many small columns, or a combination of both. The length of red rot decay columns is therefore so variable that volume losses in a living tree cannot be reliably estimated.

Defect in Relation to Parent Soil Material

Conclusions from a previous lumber recovery study indicated that, in general, defect is more prevalent and severe on nonlimestone than limestone areas in the Black Hills (Kotok and Newport 1956). Of the five locations sampled in our study, two were on limestone and three were in areas where the parent material was granite. On limestone areas, 55 percent of the trees had red rot and 35 percent had brown rots as contrasted with 77 and 38 percent, respectively, on the granite areas. The differences were not statistically significant at the 10 percent level, however, due in part to the influence of age; 61 percent of the trees on the limestone areas were under 160 years old, compared to only 38 percent on the granite areas.

Rot Defect and Associated Fungi

Decay studies usually rely on cultural determination of the decay organisms because identification based on rot alone is sometimes erroneous, although red rot (fig. 5) and brown rots (fig. 6) have different characteristics and are easily separated.

Figure 5.--Cross section of a log containing red rot. Advanced decay usually results in a cavity around the knot in which the decay entered the trunk heartwood. Incipient decay then radiates outward from the trunk in a spokelike manner.

It was not possible, however, to make isolations from columns of decay in logs that were to be cut into boards. Isolations from cull logs in the field allowed a partial identification of rot columns in these adjacent logs which were cut in the mill.

A total of 426 isolations were made from decay: 278 from white-pocket rot assumed to be red rot, and 148 from brown rot. Of the suspected red rot cultures, 236 were identified as P. anceps. Only 28 of the brown rot cultures were identified and another 20 were grouped into three definite unknown species. The remainder of the cultures were either contaminated or could not be identified.

While most Polyporus anceps in this study was identified only by its white-pocket rot, the many cultures of P. anceps taken from rot in the cull logs suggest that the determinations were generally valid. However, because P. anceps is presently undergoing taxonomic study, some reservations must be made concerning the decay ascribed to the organism. The apparent lack of other white-pocket rot fungi in the Black Hills pine remains questionable. Several cultures from white-pocket rots remain unidentified and may later be described as other species of decay fungi.

All identifications of specific brown rot organisms were from cultures isolated from cull logs. No attempt was made to differentiate between the species of brown rots on the exposed log ends because information is lacking on the causal fungi.

The high proportion of brown rots was unexpected; over a third of the trees in this study were

Figure 6.--Cross section of a log containing brown cubical rot which entered through a large dead branch. Advanced decay usually results in a circular cavity in the trunk heartwood. Incipient decay is usually circular in shape and often regular in outline.

infected. Of the 11 or more suspected species of brown-rotting fungi involved, only 5 have been identified. Table 6 lists the known brown rot fungi and the amount of defect they caused. Defect volumes attributed to the various brown rot fungi in table 6 cannot be compared because only 17 percent of the brown rot volume was identified.

Veluticeps berkeleyi caused extensive butt and trunk rot and cull in older trees (205-300 years), and may be the most damaging brown rot of pine in the Black Hills. Entrance points of decay were old fire wounds and dead branch stubs. The decay columns were extremely long, extending in a continuous column for distances of 50 to 80 feet, often to within 10 feet of the tree top. The identity of the decay organism remained in question until 1966 when it was established in a sporophore study of the fungus (Gilbertson et al. 1968).

Prior to the study, Polyporus schweinitzii was suspected of causing most of the brown rot in the Black Hills. It gains entrance through basal wounds such as fire scars, and causes extensive butt rot in older trees. Its apparent importance as a butt rot would probably have been greater if all butt rots had been identified.

Coniophora puteana is a fairly common decay fungus in living Engelmann spruce, Picea engelmannii Parry, (Hinds and Hawksworth 1966) and subalpine fir, Abies lasiocarpa (Hook.) Nutt. (Hinds et al. 1960) in Colorado. The single isolation of this organism from ponderosa pine in the Black Hills does not necessarily mean that it is of minor importance. It caused a 30 percent defect in the tree from which it was isolated, and was no doubt present in others.

Merulius himantioides is usually a decayer of slash and has been associated with the deterioration of beetle-killed Engelmann spruce (Hinds et al. 1965). It was associated with old trunk wounds in this study, and caused only minor amounts of defect.

The importance of Poria alpina as a decay of conifers remains to be determined, for its cultural identification has only recently been completed.

Before any meaningful conclusions can be drawn about the relative importance of the brown rots, other fungi will have to be identified by intensive sporophore collecting, and additional decay studies will be required.

Sporophores and cultures of other decay fungi found on ponderosa pine slash in the Black Hills were:

Armillaria mellea (Fr.) Quel.
Coniophora spp. (four species)
Cristella sulphurea (Pers. ex Fr.) Donk.
Fomes pinicola (Swarts ex Fr.) Cke.
Hyphodontia aspera (Fr.) Erikss.
Lenzites saepiaria Wulf. ex Fr.
Merulius americana Fr.
Merulius sp.
Peniophora gigantea (Fr.) Mass.
Peniophora spp. (two species)
Polyporus dichorous Fr.
P. sanguineus L. ex Fr.
P. sulphureus Bull. ex Fr.
Poria cinerascens Bres.
P. rixosa Karst.
P. vaporaria (Pers. ex Fr.) Cke.

Table 6.--Fungi associated with brown rot

Fungus	Number of trees	Total tree volume		Average percent defect	
		Bd. ft.	Cu. ft.	Bd. ft.	Cu. ft.
Veluticeps berkeleyi Cooke	3	1,910	343.9	53	37
Polyporus schweinitzii Fr.	3	1,390	242.3	35	14
Coniophora puteana (Schum. ex Fr.) Karst	1	610	107.8	30	16
Poria alpina Litsch.	5	2,750	513.8	20	10
Merulius himantioides Fr.	2	970	196.5	5	1
Total	14	7,630	1,404.3	50	16

Poria spp. (two species)
Trametes americana Overh.
Varia grandulosa (Pers. ex Fr.) Lau.

Some of these fungi are known to cause decay in living trees, while others are slash decay organisms. Their role in decay of living trees in this study was not determined.

Summary

Rot losses in sawtimber pine stands in the Black Hills were evaluated in conjunction with a lumber grade recovery study. Boards with decay cut from 1,468 logs of 498 trees from five areas were photographed after being sawed in the mill. Supplemental data were obtained from log diagram forms and 257 dissected cull logs in the woods. Decay fungi were isolated from cull logs.

Total defect for all trees amounted to 19.2 percent of the gross volume; red rot caused by *Polyporus anceps* was responsible for 8.6 percent and brown cubical rots 7.3 percent. The remaining 3.3 percent was attributed to defects other than rot. The relationship between average defect, tree gross volume, and tree age was analyzed. Rot losses amount to over 15 percent in trees older than 250 years, about 7 to 11 percent in trees less than 200 years old, and about 7 percent in trees 150 years old. Rot will continue to be the greatest cause of defect even in second-growth stands on a 120-year rotation. In such stands, red rot losses should be about 3 percent, brown rot 2 percent, and other defects 2 percent.

Red rot was present in 68 percent of all trees and in 26 percent of the logs, whereas brown rot was present in 36 percent of all trees and in 12 percent of the logs. Only 36 percent of the logs were free from defect. *Veluticeps berkeleyi* and *Polyporus schweinitzii* appear to be the important brown rot fungi; but only a small volume of the total brown rot volume has been identified.

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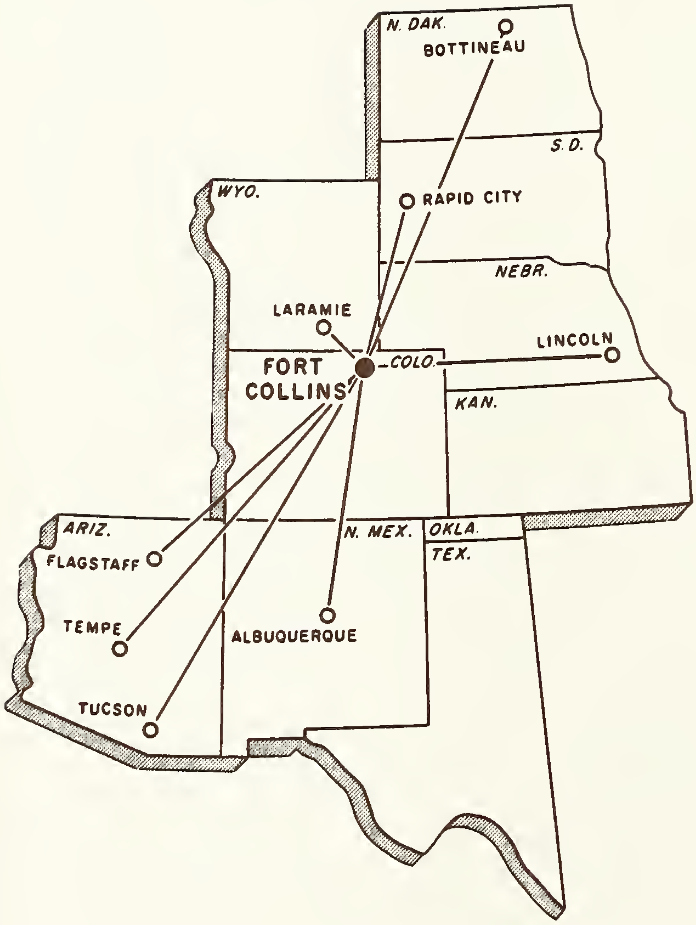

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